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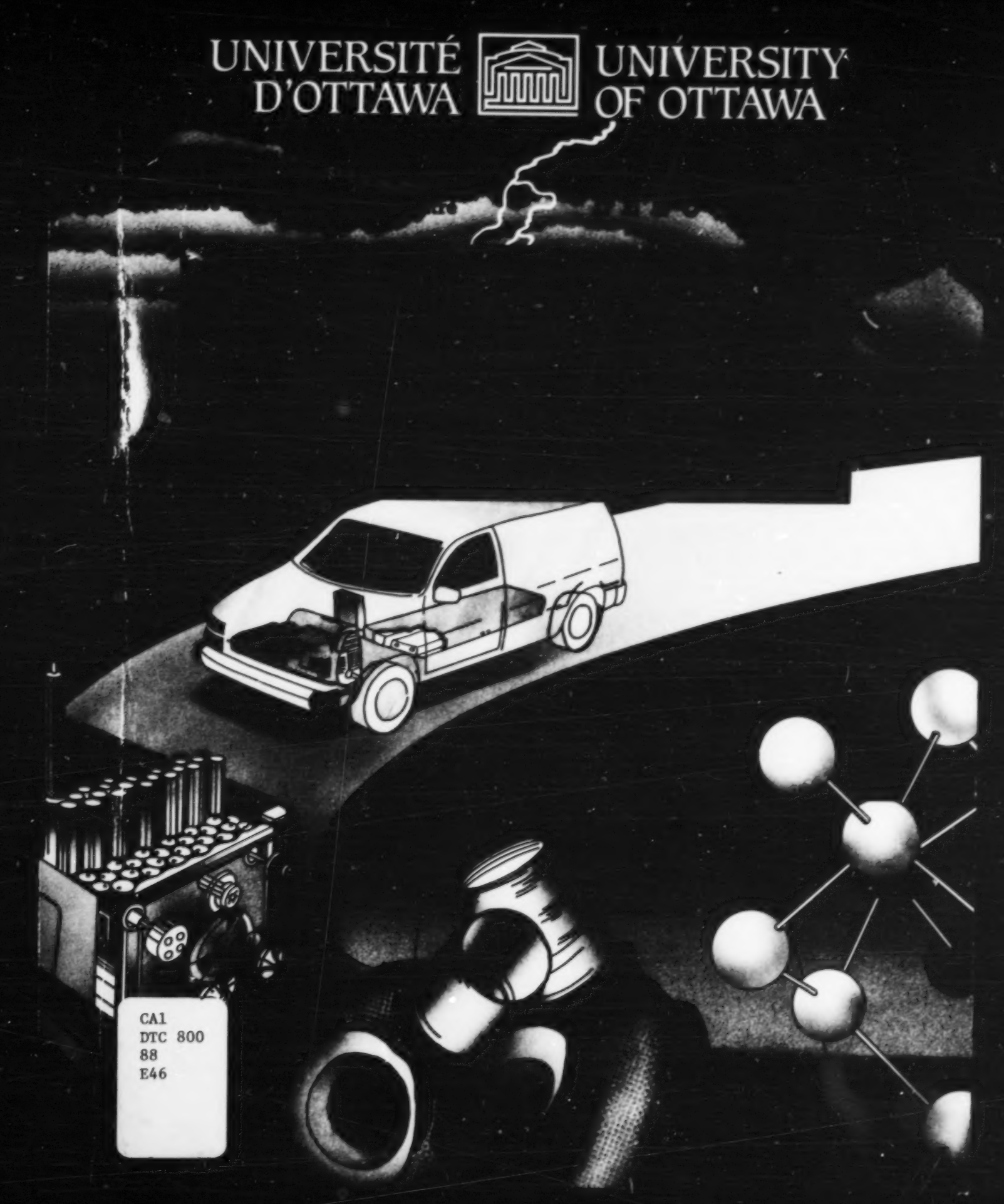

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Electrical Power Sources Inventory for Transport Canada

Prepared for

Transportation Development Centre
Policy and Coordination Group
Transport Canada

December 1988

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Transports Canada

by

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The contents of this report reflect the views of the author and not necessarily the official view or opinion of the Transportation Development Centre of Transport Canada

Un sommaire en français de ce rapport est inclus avant la Table des matières

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16. Abstract

A project involving a systematic inventory of various power sources for Transport Canada was sponsored by TDC. The study was intended to provide users and suppliers with information on a wide variety of available systems to meet the user requirements.

This report, besides providing information on power sources, also includes specifications of diesel engine generators and static uninterruptible power units (SUPU's).

The report ends with some conclusions and recommendations pertinent to an increased use of microprocessor-based devices, hybridizing of existing systems for maximum efficiency and an evaluation of past performances of power source systems.

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16. Résumé

Ce rapport concerne le recensement systématique des sources d'énergie utilisées par Transports Canada. Lancée à la demande du CDT, la recherche a voulu rassembler une information pouvant intéresser tant l'utilisateur que les fournisseurs et permettre à ces derniers de faire des soumissions susceptibles de convenir á l'utilisateur.

En outre, le rapport donne la fiche technique de divers groupes électrogènes et de chaînes statiques d'alimentation sans coupure (SUPU).

Les recommandations formulées soulignent l'intérêt accru que présentent les convertisseurs pilotés au moyen de microordinateur et les convertisseurs de type hybride à rendement optimisé; le rapport se termine par une évaluation du rendement connu des divers types de sources d'alimentation recensés.

17. Mots clés	18. Diffusion
Accumulateurs, convertisseurs thermo-électriques, chaînes statiques, convertisseurs photovoltaïques, éoliennes, piles à combustible, groupes électrogénes diesel	Le Centre de développement des transports dispose d'un nombre limité d'exemplaires.

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MG : Marine Group
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SUMMARY

i. Introduction

Due to the vast improvement of power sources technology in recent years, Transport Canada is faced with a difficult task of system-updating. However, because of man-power shortages experienced by Transport Canada, it has not been possible to determine a precise measure of currently available systems, their manufacturers and their performance.

It is obvious that the different groups within Transport Canada have different power requirements and problems associated with their electrically operated systems. For example, while the Marine Group is concerned with salt water corrosion of its marine lighting devices, the Airports Authority Group must find a way to power its hazard beams located on remote mountain-top regions without the high costs of frequent refuelling. Also, while the air traffic control equipment employed by the Aviation Group requires power supplies with an accuracy of better than 1%, such accuracy is not required by many marine applications such as floating buoys and light stations.

Although the requirements vary widely between groups and regions, it is possible to find common elements in order to standardize some of the systems. For example, SUPUs (Static Uninterruptible Power Units), which are employed indoors by many groups for similar applications, are a possible candidate for standardization. This would not only result in cost savings, but in greater operational effectiveness in the long run. This report is not intended as an evaluation of current practice, but as a reference for the wide variety of systems now available and the power source requirements of various groups within Transport Canada.

ii. Summary of Contents

Batteries are the most numerous power sources and they are found in all systems and applications concerning the power sources employed by Transport Canada. The majority of the batteries used are of the lead-acid type. There are approximately 50,000 battery packs of different types and sizes of cells used today by various groups within Transport Canada.

Another common power source is the motor/generator set. The fuel used in these systems is diesel because of its high efficiency and ready availability. Diesel engines are considered to be more durable and dependable than any of the other non-conventional power systems. Diesel engine generators are capable of generating electrical power from a few kilowatts to megawatts of power. Therefore, they offer power system designers great flexibility. About 1,500 small, medium and large diesel generators are in operation today by Transport Canada.

Photovoltaic (PV) power systems have been successfully introduced by the Marine Group. They have replaced a number of diesel engine generators and expensive primary batteries used for minor light stations and floating buoys. However, the PV systems need improvement in reliability and capacity (per given PV area) before they are introduced by other groups. Approximately 2,500 systems are now in use by Transport Canada, mostly by the Marine Group.

For those locations where ac utility power is available, SUPUs can be used effectively as back-up power sources to ensure the continuity of ac power. SUPUs are small and clean, and suitable for indoor use. Typical applications are for back-up power for computer systems, air traffic control equipments and communication links. The Aviation Group is the largest SUPU user with 400 systems, followed by the Airports Authority Group which employs about 150 SUPU systems.

Other systems such as wind power, thermoelectric generators and nuclear sources play only a minor role in Transport Canada.

Although they might meet the power requirements, the cost/energy ratio is too high at their current stages of development and their availability might also be a cause for concern. The wind power system suffers from inconsistent generating capacity. Thermoelectric generators, nuclear sources and fuel cells are in competition with diesel engine generators; however, diesel engine generators are preferred today because of low fuel cost in most locations and also, the new and improved diesel generating machines offer excellent reliability. However, recent developments in fuel cell technology largely sponsored by defense interests will likely result in methanol-fuelled fuel cells for field applications within the next three to seven years. These units may also operate on natural gas and could offer good prospects in remote areas where supplies of natural gas are available.

SOMMAIRE

i. Introduction

Les progrès fulgurants réalisés dans le domaine des convertisseurs d'énergie au cours des dernières années a mis Transports Canada devant l'obligation de moderniser les systèmes qu'il utilise; cependant, une pénurie de personnel qualifié a jusqu'ici empêché le Ministère de cerner ses besoins exacts, et ses divers services de tirer profit des nouvelles technologies sur le marché.

De toute évidence, les divers groupes fonctionnels de Transports Canada ont des besoins et des problèmes différents en matière d'alimentation électrique. Ainsi, le Groupe maritime se préoccupe beaucoup de la corrosion de ses balises lumineuses par l'eau de mer tandis que le Groupe gestion des aéroports doit trouver une solution au problème de l'alimentation des balises implantées en sites montagneux tout en évitant des ravitaillements répétés et coûteux. De même, alors que le Groupe aviation exige pour ses équipements de contrôle de la circulation aérienne une régulation de la tension à moins de 1 p. 100 près du régime établi, une telle stabilité n'est guère requise à l'égard d'un grand nombre de dispositifs d'éclairage maritimes, les balises flottantes et les phares, par exemple.

Malgré les diversités fonctionnelles ou régionales, il existe des éléments communs à tous les systèmes, donc qui se prêtent à la standardisation. Par exemple, les chaînes statiques d'alimentation sans coupure (SUPU) que bon nombre de groupes fonctionnels utilisent; leur standardisation promet non seulement des économies d'ordre financier, mais aussi une efficacité à long terme accrue. Le présent rapport ne constitue pas une évaluation des pratiques actuelles; il se veut un guide destiné à informer les groupes fonctionnels de Transports Canada sur les nombreux systèmes présentement sur le marché et à guider leur choix en fonction des critères qui leur sont propres.

ii. Aperçu technique

De tous les convertisseurs statiques que Transports Canada utilise pour ses besoins en énergie, les batteries d'accumulateurs sont les plus répandues. On en compte près de 50 000, la plupart du type plomb-acide, de toutes tailles, au service des divers groupes fonctionnels du Ministère.

Viennent ensuite les groupes électrogènes, équipés de moteurs diesel dont les avantages sont le rendement élevé du carburant diesel ainsi que sa grande abondance. Les groupes électrogènes diesel sont plus durables et plus fiables que tous les convertisseurs d'énergie non classiques. La puissance unitaire de ces groupes peut aller de quelques kilowatts à plusieurs mégawatts, offrant une gamme d'utilisation que le concepteur de systèmes électriques peut aisément mettre à profit. Il existe actuellement quelque 1 500 groupes électrogènes diesel, petits, moyens et grands, exploités par Transports Canada.

Les convertisseurs photovoltaïques ont remplacé avec succès, au sein du Groupe maritime, nombre de groupes électrogènes diesel et de batteries primaires d'exploitation coûteuse pour l'alimentation de phares et de balises flottantes de faible puissance. Toutefois, leur fiabilité ainsi que la puissance qu'ils fournissent par unité de surface captrice devront être relevées avant que d'autres groupes puissent commencer à s'y intéresser. Environ 2 500 convertisseurs sont présentement utilisés surtout par le Groupe maritime.

Les installations reliées à un réseau de distribution électrique peuvent compter sur les chaînes statiques d'alimentation sans coupure (SUPU) comme groupe d'intervention en cas d'une coupure de l'alimentation. Ces appareils d'intérieur occupent peu d'espace et ne polluent pas. Ils servent surtout à la protection des systèmes informatiques, des aides à la navigation aérienne et des systèmes de communication. Le plus important utilisateur, le Groupe aviation, emploie 400 SUPU, suivi du groupe Gestion des aéroports qui en utilise près de 150.

Quant aux autres systèmes fournisseurs d'énergie, - éoliennes,

convertisseurs thermoélectriques et nucléaires - ils sont peu utilisés par Transports Canada, et, bien qu'ils répondent aux critères applicables, le coût unitaire de l'énergie fournie est encore trop élevé à ce stade-ci du développement. De plus, le fait qu'ils sont fabriqués en petites séries les rend encore plus sujets à caution. Le désavantage des éoliennes est la faible quantité d'énergie qu'elles garantissent. En ce qui a trait aux convertisseurs thermoélectriques et nucléaires et aux piles à combustible, ils doivent concurrencer les groupes électrogènes diesel, les favoris encore de nos jours, à cause du prix très abordable du combustible dans la plupart des régions et aussi de la très haute fiabilité des groupes maintenant disponibles sur le marché. Il se peut, cependant, que les progrès réalisés dans le domaine des piles à combustible sous l'impulsion des besoins militaires débouchent sur la mise au point d'une pile à méthanol d'ici trois à sept ans. Ces piles aptes à fonctionner aussi au gaz naturel offrent de bonnes perspectives d'utilisation dans les sites isolés où le combustible se trouve en abondance.

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1. INTRODUCTION

A wide variety of electrical systems containing batteries are currently employed for various applications within Transport Canada. The areas in which these devices are effectively used range from small remotely-located navigational aids to batteries and/or fuel cells to power road vehicles.

During the last decade, industry and government laboratories have made significant progress in the development of advanced battery systems and fuel cells. In order to arrive at a more precise measure of the demand for this new technology within Transport Canada, a systematic survey of power sources in use has been undertaken so that the agencies developing various power systems would be aware of specific application requirements, and so that potential Transport Canada users could be made aware of new options as a consequence of these developments.

2. OBJECTIVES

2.1 MODAL OBJECTIVE

To address technology developments which apply to more than one mode of transport and have the potential for improving the safety, efficiency or overall effectiveness of the transportation system.

2.2. MODAL SUB-OBJECTIVE

To undertake studies and surveys of power sources, electrical, electronic or mechanical sub-systems which are used in more than one mode of transportation with a view to standardization and consequent economies.

2.3 PROJECT OBJECTIVE

To develop an inventory of power sources used by the Canadian Coast Guard, the Aviation Group and the Airports Authority Group in order to define the current and future requirements of Transport Canada for these power source devices.

3. METHOD OF SURVEY

The survey involved telephone conversations and personal contacts with a number of Transport Canada personnel from the Marine, Aviation and Airports Authority Groups. In addition to this, a significant effort was made in studying the relevant literature, i.e., reports and publications. Most of the information required for the report was obtained during telephone conversations or at meetings. Some was sent to the authors by mail following the meetings. None of the information was classified as "sensitive material" and therefore readily accessible.

Based on this survey, the report has been classified into sections dealing with batteries and fuel cells, and their incorporation as applicable, into various power systems as follows:

- Thermoelectric Generators
- Motor/Generator Sets
- Photovoltaic
- Uninterruptible Power from Utility
- Wind Power

Each system is sub-divided based on the information provided by the Marine, Aviation and Airports Authority Groups.

Not every manufacturer or supplier of systems is mentioned in the report. Some companies are excluded from the report because of the small number of their products in use. Also, many numbers (i.e., number of total systems) are estimated since determining the actual numbers was not practical in many instances. The estimated values are thought to be adequate for planning purposes.

4. BATTERIES

The many and varied requirements for power and the different environmental and electrical conditions under which they operate necessitate the use of a number of different types of batteries and battery designs, each having superior performance under certain operational conditions.

Although many advances have been made in battery technology in recent years, there is still not an "ideal universal" battery that gives optimum performance under all operating conditions. As a result, many electrochemical systems and battery types have been and are being investigated and promoted.

Batteries can be found in all systems and applications concerning the power sources employed by Transport Canada. Rechargeable lead-acid batteries are used as storage batteries for static uninterruptible power units (SUPUs), motor/generator sets, photovoltaic and wind power systems. Also, non-rechargeable batteries can be found in many applications such as power sources for remote area beacon transmitters, EPIRBs (Emergency Position Indicating Radio Beacons[1]), floating buoys and hand-held communication devices.

Lead-acid batteries[2] account for almost all the batteries used by Transport Canada today with the exception of some nickel cadmium batteries. With the practical operating capacity of approximately 35 Wh/kg at row rate and good cycle life at many shallow discharge applications, they usually meet or exceed the power and service requirements of many Transport Canada applications. Although the lead-acid battery system is by no means the best in performance, it combines important characteristics such as relatively low cost with acceptable performance and cycle life, and offers the best value-for-money at this stage of battery

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[1] Battery type has not been determined yet

[2] Sealed lead batteries are most commonly used to minimize maintenance

development.

Currently, we estimate that more than 50,000 batteries of various types and sizes are being used by different groups of Transport Canada. The exact number and the types of batteries cannot be precisely determined because the batteries are selected and purchased at a regional level and purchase records are not reported to Transport Canada headquarters. The task of determining the exact number and the types of batteries would involve contacting every airport, remote communication facility and regional coast guard office. The cost of such a lengthy and difficult task would easily outweigh its importance.

Exide, Gates, Globe and Union Carbide are the major manufacturers currently supplying Transport Canada with primary and secondary batteries. Since these manufacturers provide products that satisfy or surpass the currently specified performance requirements of Transport Canada, the only factors affecting the decision making of each group is the cost and availability of the required batteries.

4.1 RECHARGEABLE BATTERIES

Rechargeable(or secondary) batteries are characterized by high power density, high rate flat discharge curves, and low-temperature performance adequate for some but unsatisfactory in other applications. Their energy densities are generally lower than those of primary batteries and their charge retention is also poorer than most primary batteries. They are used as an energy storage device, generally connected to and charged by a prime energy source and delivering their energy to the load on demand. Examples of this type of service within Transport Canada are diesel engine starting, lighting and standby electrical systems[3].

4.1.1. Marine Group

- **Applications**
  - Diesel engine starting and storage batteries at all of 270 automated major light stations and 3,500 minor light stations.
  - storage batteries for 2,000 PV systems at minor light stations and floating buoys.
  - Storage batteries for 50 SUPU systems

- **Manufacturers/Suppliers**
  Union Carbide, Exide and Globe

- **Capacity**
  - 400 Ah to 600 Ah, or 48 hrs stand-by capacity at emergency level required for light stations
  - 20 Ah to 40 Ah required for SUPUs

---

[3] All the rechargeable batteries used are maintenance-free type and do not require electrolyte refilling unlike other Federal agencies such as DND that are reluctant to use maintenance-free type batteries

- **Voltage**
  12 V, 24 V or 36 V dc[4]

- **Current**
  - 5 A to 2[illegible] A constant current for lighting purpose
  - 400 A to 500 A peak for diesel engine starting purpose

- **Duty Cycle**
  - 50% for lighting purpose
  - Instantaneous for diesel engine starting
  - 0% or 100% for SUPU systems

- **Environmental Constraints**
  - Ambient temperature range for PV system : -60°C to +40°C
  - Heated storage room required for some locations
  - 500 A peak for cold cranking diesel engine

- **Replacement Schedule**
  5 to 7 years

- **Service Requirements**
  - Check voltage level and clean batteries once a year
  - Check operation of charger and voltage regulator once a year

- **Charging Protocol**
  Limited current-Constant voltage charging

4.1.2. AVIATION GROUP

- **Applications**
  Storage batteries for SUPU systems, and starting and storage batteries for diesel engine generators

- **Manufacturers/Suppliers**
  Gell/Cell type by Globe

- **Capacity**
  150 Ah - 300 Ah

---

[4] will go to 48 V dc in future.
24 V battery is two 12 V batteries connected in series

- **Voltage**
  12 V, 24 V, 36 V or 48 V dc

- **Current**
  - For 8 hr SUPU
    - 25 A max for 12 min of each hour
    - 7 A max for 28 min of each hour
  - For 30 min SUPU
    - 50 A max for 6 min
    - 14 A max for 24 min
  - 500 A peak current for diesel engine starting

- **Duty Cycle**
  - **SUPU systems**
    - 100% during ac power failure
    - 0% otherwise
    - Instantaneous for diesel engine starting

- **Environmental Constraints**
  The batteries, including SUPU, are to perform at all temperatures between -10°C and +50°C; in an ambient relative humidity range of 40% to 90%; and at altitudes from sea-level to 3,000 m.

- **Replacement Schedule**
  6 to 8 years

- **Service Requirements**
  - Check operation of voltage regulator and charger once a year
  - Check for electrolyte leakage periodically
  - Check voltage level periodically

- **Charging Protocol**
  Limited current-constant voltage method for best result.(2.4 volt/cell for maximum float life)

4.1.3. AIRPORTS AUTHORITY GROUP

- **Applications**
  - Storage batteries for SUPU systems, photovoltaic power systems and wind power systems
  - Starting and storage batteries for diesel engine generators

- **Manufacturers/Suppliers**
  Globe, Union Carbide

- **Capacity**
  2.5 kWh to 600 kWh

- **Voltage**
  24 V to 48 V dc

- **Current**
  - 5 A to 20 A for emergency and hazard lights
  - 50 A 200 A for runway lights
  - 100 A to 400 A in the event of airport power failure

- **Duty Cycle**
  - 50% for lighting
  - 100% during power failure for SUPU systems
  - Instantaneous for diesel engine starting

- **Environmental Constraints**
  - Ambient temperature range: -40°C to 50°C
  - Ambient humidity range: 40% to 90%
  - Operating altitude: sea level to 3000 meters

- **Replacement Schedule**
  6 to 10 years

- **Service Requirements**
  - Clean Batteries and check voltage once a year
  - Check voltage and current limiter of charger periodically

- **Charging Protocol**
  Constant voltage - limited current

4.2 NON-RECHARGEABLE BATTERIES

The primary (non-rechargeable) battery is a convenient, usually relatively inexpensive, light weight source of packaged power for portable electronic and electrical devices. Primary batteries are used typically from low to moderately high power drain applications, in most cases in the familiar flat, button, or cylindrical cell configurations. Non-rechargeable batteries are used for special applications where their high capacity and energy density, long shelf life, and freedom from recharging and maintenance are important requisites.

4.2.1. MARINE GROUP

- **Applications**
  - 3500 Floating Buoys (cylindrical "dry" cell)
  - EPIRBs[5]
  - hand-held communication devices

- **Manufacturers/Suppliers**
  Union Carbide, Exide

- **Capacity**
  2 Ah - 350 Ah

- **Voltage**
  3 V - 12 V dc

- **Current**
  - 20 mA to 500 mA for hand-held communication devices
  - 5 A to 10 A for floating buoys

- **Duty Cycle**
  - Floating buoys: 100%
  - EPIRBs: 1%
  - Hand-held communication device: 10 to 50%

---

[5] Lithium batteries with a life of 5 years between replacement are being considered by the Canadian Coast Guard for on-board EPIRBs.

- **Environmental Constraints**
  Withstand extreme humidity and corrosion from salt water and ambient temperatures from -40°C to 50°C

- **Replacement Schedule**
  - 9 month to 12 month for floating buoys
  - 5 years for EPIRBs
  - 6 months for hand-held communication devices

- **Service Requirements**
  Buoys on East Coast are brought ashore in winter, ie. only one year service required.

4.2.2. AVIATION GROUP

-**Applications**
  Power source for remote area beacon transmitters[6]

- **Manufacturer/Suppliers**
  Globe, Union Carbide

- **Capacity**
  1000 Ah to 1500 Ah

- **Voltage**
  12 V dc, 24 V dc

- **Current**
  0.5 A

- **Duty Cycle**
  Approximately 10%

- **Environmental Constraints**
  Provide long shelf-life at low ambient temperature.

- **Replacement Schedule**
  2 years

---

[6] Modern aircraft with advanced navigation systems do not require service of directional beacons and number of beacon transmitters are decreasing

- **Service Requirements**
  When radio signal indicating power failure is received, replace whole battery system

4.2.3. AIRPORTS AUTHORITY GROUP

The only non-rechargeable batteries (some Ni/Cd rechargeable batteries may also be in use) used by Airports Authority Group are small cylindrical cells used for portable electronic devices used in security checks. The number of batteries required and their characteristics were not available at the time of writing. However, the reliability of these devices is critical to flight safety and depends on the users being familiar with the characteristics of the type of batteries being employed and following correct procedures for battery testing and replacement during the operation of the battery powered equipment.

5. THERMOELECTRIC GENERATORS

Thermoelectric power generators have been developed principally for applications in space vehicles, in military equipment, for the supply of stand-by auxiliary power and service power at remote sites. Since there are none of the failure mechanisms that one finds in storage batteries, the shelf-life of a thermoelectric device is extremely long; usually more than 10 years. It is almost instantly ready to operate when heat is applied. As development continues toward the tentative goal of 30 per cent efficiency[7], it is conceivable that very large quantities of auxiliary power may be supplied in this way.

The choice of a thermoelectric power source over other sources of electric power will be governed by a number of factors. Thus cost, reliability, efficiency, fuel type and temperature of heat source, type and temperature of heat sink, weight, and many other variables need consideration in making this selection.

Despite their present relatively low efficiency and low power-to-weight ratio[8], thermoelectric generators are already beginning to find a number of actual and potential applications. This is due in part to their unique combination of properties:

1) There are no moving parts.
2) Operation can be silent.
3) Operation is unaccompanied by the gyroscopic effects associated with rotating machinery
4) Since thermoelectric effects are electronic in nature, there need be no chemical changes in the materials and their potential life is long in a well-designed device.
5) Their design is very flexible, as thermocouples may be assembled on flat plates, cylinders, spheres, or in whatever form may be suitable for any particular heat source or sink.

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[7] Currently, efficiency is less than 10%

[8] Output power of today's generators are approx. 1 kW

The above observations suggest that, with improved efficiency and increase in price of diesel fuel, thermoelectric generators could be effectively used in place of some of the diesel engine generators at selected locations in the future. Currently, only four thermoelectric generators are seeing limited service by Airports Authority Group to generate power for hazard beams located on remote mountain areas in Alberta and their performance is being monitored by both the Airports Authority Group and the Transportation Development Centre.

5.1. MARINE GROUP

None

5.2. AVIATION GROUP

None

5.3. AIRPORTS AUTHORITY GROUP

- **Manufacturer/Suppliers**
  Global

- **Fuel source**
  Propane

- **Power level**
  150 W capacity
  - 120 W during night time
  - 60 W during twilight

- **Voltage**
  24 V dc

- **Current**
  3 A - 5 A

- **Environmental constraints**
  none

- **Service requirement**
  Check system and fuel once every six month

6. MOTOR/GENERATOR SETS

Motor/Generator sets are the most familiar power systems which can be used either as main power source or as back-up power source. Once installed, they require regular maintenance. The power output can easily be modified by varying the engine rpm or by choosing different sizes of engines to give power system designers much needed flexibility but care must be taken to provide a system optimized with respect to efficiency if fuel costs are to be controlled. The service life of a diesel engine generator can be extended up to 50 years or longer by following the maintenance procedure provide by the manufacturers. Some of the generators in operation today were installed just after the Second World War and are showing no signs of aging.

The only fuel considered for motor/generator sets used by Transport Canada today is diesel. A stationary diesel engine converts up to 40% of its fuel into usable power under ideal operating conditions whereas a gasoline engine and a steam engine yields approximately 25% and 6% efficiency, respectively.

Today, one or more diesel engine generators can be found in every small and large airport, marine station and air traffic control site. The newer models are equipped with built-in battery charging systems and the older models are connected to external battery charging devices. Every diesel engine generator is accompanied by batteries with enough power to start the engine under any circumstance. Some generators at unmanned stations are connected to standby batteries which supply power to the equipment in emergency situations should the engine fail. Also, in some remote locations, a radio signal is transmitted to the nearest manned site should the diesel generator experience a malfunction.

Another method of ensuring continuity of power is to use a cycle charge diesel generator system (also called a dual-diesel generator). In this power system, if a built-in microprocessor detects any malfunctioning of one generator, it immediately starts the back-up generator and the equipment is switched to it.

Diesel engine generators are also used as back-up power sources during ac power failure or for photovoltaic and wind power hybrid systems. In these cases, especially when they are used for ac power back-up, diesel engines must be operated at least once in each 3-month period.

Specifications of diesel engine generators vary depending on load requirement, location and power systems. A general specification for "Stand-by hydro" dual diesel engine power systems used by the Canadian Coast Guard at automated light stations is summarized in Appendix B[9].

[9] Courtesy of Aids and Waterways, Canadian Coast Guard

6.1. MARINE GROUP

- **Applications**
  Single and dual diesel engine power systems for use at automated light stations

- **Manufacturers/Suppliers**
  Westinghouse, General Electric and Bogue Electric

- **Type of Unit**
  Diesel engine generators[10]

- **Capacity of Generator**
  5 kWh to 100 kWh

- **Duty Cycle**
  Continuous 24 hour service at full and/or part load and 10% overload for one hour in any 12 hour period.

- **Voltage**
  12V - 250V D.C.

- **Current**
  5A - 200A

- **Service Requirements**
  - Follow manufacturer's suggested service procedure
  - Check voltage and current of charging system

- **Environmental Constraints**
  - Capable of being started electrically at all temperatures between 0°C to 38°C unassisted by such devices as heaters, glow plugs, etc.
  - Capable of operating at relative humidity of 60%

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[10] Equipped with a 12 volt D.C. engine starting electric motor, batteries and a charger

6.2. AVIATION GROUP

- **Applications**
  Back-up power systems for air traffic control and communication equipment

- **Manufacturers/Suppliers**
  Westinghouse and General Electric

- **Type of Unit**
  Diesel

- **Capacity of Generator**
  100 kWh to 500 kWh

- **Duty Cycle**
  - 100% during ac power failure
  - 0% otherwise

- **Voltage**
  12 V, 24 V, 36 V dc

- **Current**
  Up to 500 A

- **Service Requirements**
  - Manufacturer's suggested service to be followed
  - Battery charging system to be periodically checked

- **Environmental Constraints**
  Capable of being started at -30°C

6.3. AIRPORTS AUTHORITY GROUP

- **Applications**
  - Remote area hazard and emergency lights and airports
  - Directional beams
  - Air traffic control equipment back-up or main system
  - Interruptible power units (IPUs)

- **Manufacturers/Suppliers**
  BBC, Westinghouse, Bogue Electric, General Supply, Kato, Tamper, Fidelity, Canron, General Electric, Leland, Columbia

- **Type of Unit**
  Diesel

- **Capacity of Generator**
  2.4 kW - 600 kW

- **Duty Cycle**
  50% to 100%

- **Voltage**
  - 12 V dc and up
  - 120/208 V ac for IPUs

- **Current**
  Up to 800 A

- **Service Requirements**
  - Follow manufacturer's suggested service procedure
  - Check operation of charging system periodically

- **Environmental Constraints**
  Capable of being started at -30°C

7. PHOTOVOLTAIC SYSTEMS

Applications for which photovoltaic is presently considered a viable power source can be characterized as being located in remote areas and consuming less than 1 kW of low voltage (less than 50 V) dc power. In Transport Canada, the power sources for minor light stations and floating buoys employed by the Coast Guard are currently being converted from diesel engine generators to photovoltaic power systems. The conversion program for minor light stations began in the late 1970's and 3 years after they were installed, the cost of installing photovoltaic systems could be recovered. The photovoltaic systems also proved to be quite reliable. Only two system failures were reported out of 2000 minor light stations equipped with photovoltaic power systems since their installation.

Solar cells can only produce electricity when the sun is shining on them and so, to maintain continuity of power supply, it is necessary that, depending on the load, the photovoltaic power system include either an energy storage unit or a tie-in with a non-solar generating plant.

Even though the photovoltaic conversion program by the Marine Group has proven to be quite successful, the Airports Authority and the Aviation groups are reluctant to consider photovoltaic systems for their applications. This is because air transportation, in contrast to marine transportation, deals with short time scales and therefore requires power sources of greater continuity and faster response times such as SUPUs or diesel engine generators. A total of 10 photovoltaic power units are employed by Airports Authority Group in Newfoundland as power sources for hazard beacons.

7.1. MARINE GROUP

- **Applications**
  land based minor light stations, floating buoys

- **Manufacturers/Suppliers**
  Lenbrooke Industry

- **Capacity of PV System**
  5 W, 10 W, 20 W, 30 W

- **Storage Capacity and Type**
  60 Ah to 200 Ah with 12 V, 24 V or 36 V lead acid battery banks

- **Current**
  0.25 A to 15 A

- **Voltage**
  12 V, 24 V, 36 V dc

- **Environmental Constraints**
  - Ambient temperature range: -60 to 40°C
  - Maximum possible humidity range over the above temperature range
  - Withstand wind loading up to 175 km/h from any horizontal direction
  - Withstand coastal corrosive condition caused by continuous exposure to salt laden air and sea splash
  - Surface material must withstand the impact of ice spray and hailstone of 25 mm diameter at an impact velocity of 20 m/s
  - Withstand strains, shocks, vibrations and conditions incident to operation such as wave action

- **Service Requirements**
  - Surface area be cleaned once a year
  - Battery charging system be checked once a year

7.2. AVIATION GROUP

None

7.3. AIRPORTS AUTHORITY GROUP[11]

- **Applications**
  Hazard beacons

- **Manufacturer/Suppliers**
  - Global Industry (supplier: Mechron Co. , Ottawa, Ont.)
  - TPK International

- **Capacity of PV System**
  100 W

- **Storage Capacity and Type**
  100 Ah with 24 V dc battery bank

- **Current**
  0.5 A - 5 A

- **Voltage**
  24 V dc

- **Environmental Constraints**
  - Ambient temperature range: -60°C to 40°C
  - Withstand coastal corrosive condition caused by continuous exposure to salt laden air

- **Service Requirements**
  - Surface area be cleaned once a year
  - Battery charging system be checked once a year

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[11] All PV systems employed by Airport Authority Group are located in Newfoundland

8. UNINTERRUPTIBLE POWER FROM UTILITY

A new concept in standby power is the dc power system with battery back-up. These power systems include a battery charger (rectifier/charger) which has a sufficient capacity to recharge the batteries at the proper voltage while simultaneously supplying power to the dc load. Additionally, equipment protection and isolation of the line voltage from the secondary windings of the special power transformer are designed into the system.

A SUPU system is one such standby power system. In SUPUs, a storage battery is linked to the utility power to provide a continuity of service in the event of an interruption of the utility power. For these systems, an ac line supplies power to the stationary battery charger which, in turn, "float" charges the battery and, at the same time, supplies dc power to the stationary inverter. The inverter, in turn, supplies power to the ac load.

Applications for which a SUPU system can be effectively utilized are characterized as being located in places equipped with a.c. utility power. The output of a SUPU system depends on the capacity of the charger and the number of storage batteries. For applications requiring more than 50 volts, diesel engine generators are often considered and are more effectively used.

General specifications for all the SUPU systems employed by Transport Canada are virtually the same. The specifications on the products, due to similarity in electrical, mechanical and environmental requirements, are also very similar regardless of the group using them. The specification of a SUPU system recently acquired by the Airports Authority Group is summarized in Appendix C, and just minor modifications will be found on specifications for SUPUs of the Marine Group and the Aviation Group.

8.1. MARINE GROUP

- **Applications**
  Monitoring and communication equipment back-up at marine stations

- **Systems now in place**
  50 SUPUs

- **Specification of systems**
  Input power: 120 V ac, 10 A, single phase
  Output power: 24 V dc, 48 V dc
  (See appendix)

- **Manufacturers/Suppliers**
  Exide Electronics, Powertronics

8.2. AVIATION GROUP

- **Applications**
  Computer system back-up, weather collection, communication and navigation aid equipment back-up

- **Systems now in place**
  400 SUPU systems now in place from coast to coast

- **Specification of systems**
  - Input power:
    Nominal: 120 V ac + 10% - 15% (102 V ac - 132 V ac)
    60 Hz ± 5 Hz
    Single phase
    10 A max.
    Notes: 1. SUPU shall withstand transient of 30% of nominal voltage for 500 ms with a recovery time of less than 5 s.
    2. 1000 V Spike - The equipment shall withstand a spike of 1000 V for 10 microseconds.

  - Output power:
    24 V dc
    voltage = 24 V dc ± 10%
    ripple = 100 mV pp or 36 mV RMS

Current for 8h SUPU shall be:
25 A max for 12 min of each hour
7 A max for 48 min of each hour

Current for 30 min SUPU shall be:
50 A max for 6 min
14 A max for 24 min

- **Manufacturers/Suppliers**
  Pylon Electronics Development

8.3. AIRPORTS AUTHORITY GROUP

- **Applications**
  Electronic systems back-up power

- **Systems now in place**
  150 SUPU systems

- **Specification of system**
  See Appendix C

- **Manufacturers/Suppliers**
  Exide Electronics, Powertronics, Emergency Power Engineering (EPE)

9.0 WIND POWER

In the early 1980's, four wind power generating systems were installed around the Ottawa International Airport to supply power to hazard beams and direction indicating lights. Their effectiveness and reliability were carefully monitored by the Airports Authority Group for a number of years.

Because the wind resource is difficult to determine precisely, the energy output from a wind turbine can not be easily predicted and modelled. This environmental constraint plus high cost per energy output forced the Airports Authority Group to abandon the project. Although the systems still remain, they are not being serviced as practical power sources for any of the airport applications. For wind power generating system to be considered as practical and effective power source for applications by Transport Canada in the future, they will have to undergo major design change and the selection of optimum sites for the systems given extensive study.

9.1 MARINE GROUP

None

9.2. AVIATION GROUP

None

9.3. AIRPORTS AUTHORITY GROUP

- **Applications**
  Power system for hazard beams

- **Manufacturers/Suppliers**
  Ocean Systems

- **Capacity**
  5 kW

- **Storage Capacity**
  8.5 kWh

- **Voltage**
  24 V dc

- **Current**
  10 A to 20 A

- **Service Requirements**
  Storage battery charging systems be checked periodically

- **Environmental Constraints**
  The wind power generating systems depends on the average wind speed[12] as well as seasonal and daily variability.

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[12] Average wind velocity in Ottawa is less than 15 km/s

10. FUEL CELLS

A fuel cell system is an electrochemical system in which the chemical energy of a fuel such as natural gas, methanol or hydrogen is converted directly and efficiently into direct-current electrical energy.

The principal disadvantage of the fuel cell system is that (in contrast to combustion system) the chemical reactions associated with the energy conversion processes must take place at catalytically active solid surfaces, where they are limited by relatively slow processes of diffusion. Thus power densities of most fuel cells are often limited by the physics of diffusion, the availability of durable catalysts, and the closeness with which porous electrode surfaces can be packed within the volume of the cell.

An important advantage of many fuel cells is that they are efficient in small sizes at part load. Other advantages are low noise and minimal pollutant emissions. Another advantage is that, unlike other prime movers, their efficiency at part load is even higher than at full load. The actual efficiency depends greatly on the fuel used.

10.1 MARINE GROUP

None

10.2. AVIATION GROUP

None

10.3. AIRPORTS AUTHORITY GROUP

None

11. OTHERS

There are a number of other renewable sources of energy which could be converted to electricity. For example, energy generated from waves along the coast of Newfoundland could be transmitted to supply power to marine stations or airports, or tidal energy could be used to power some of the light stations employed by the Marine Group. Also, alternative-fuelled engines could be used in place of diesel fuel powered generators for some applications. At certain specific locations, geothermal power could be used as a source of energy. Furthermore, hybrid designs such as wind/solar or fuel cell/diesel could bring improvements in the efficiency and the cost of the existing systems. However, the above mentioned power sources generally experience a high cost/energy output at their current stage of development and thus, they are not being installed by Transport Canada at this time.

11.1. MARINE GROUP

None

11.2. AVIATION GROUP

None

11.3. AIRPORTS AUTHORITY GROUP

None

12. CONCLUSIONS

It was found from the study that batteries are used in every system and application either as main power source or as back-up power source. So far, lead-acid batteries have found the most significant role in Transport Canada and will do for some time. Another very important power source is provided by diesel generators.

However, lead-acid batteries suffer from low energy/volume ratio. Efforts are being made to adopt more superior battery systems such as Al/air and Lithium batteries in place of lead-acid batteries. It was also found that photovoltaic (PV) systems have successfully replaced diesel engine generators in a number of marine applications. The efficiency of a diesel engine is poor at low load; on the other hand, PV systems perform most effectively at low power. Therefore, the implementation of PV systems by the Marine Group for floating buoys and minor light stations seems only logical. The selection of proper locations is critical in installing PV systems or wind power generating systems. Poor selection of sights are partly responsible for failure of wind power generating systems around the Ottawa International Airport.

Static uninterruptible power units (SUPUs) seem to have very little room for improvements. All SUPUs are equipped with state-of-the-art monitoring and battery charging devices.

Systems other than batteries, diesel generators, SUPUs and PV systems play only a minor role in Transport Canada. Efforts to develop new energy sources were slowed down by the low fuel cost in most locations and advancements in existing systems.

13. RECOMMENDATIONS

i) Microprocessor-controlled devices should be adopted to improve the performance, life cycle and the efficiency of existing power source systems. For example, microprocessor-controlled charging of a diesel/photovoltaic hybrid system can substantially improve battery life and overall system performance because the effectiveness of a battery depends greatly on the charging method adopted. Also, a data acquisition system (DAS) can be used to monitor the performance of aging systems or systems located in remote areas to determine exactly when the systems or system components need to be replaced.

ii) Implementation of non-polluting and renewable energy sources such as photovoltaic, wind or fuel cells should be considered. These will not only minimize the fossil fuel dependency of Transport Canada, but will result in cost-savings in the long run.

Fuel cells are presently undergoing rapid development of systems from very small portable units of 10 watts to megawatt utility units.

iii) Studies on the long-term advantages of hybridizing existing systems (apart from batteries) are strongly recommended. Diesel/photovoltaic, fuel cell/diesel, fuel cell/photovoltaic hybrid systems all possess high potential for certain applications.

iv) For those small applications which involve conventional lead-acid battery systems, a consideration should be given to advanced power sources in view of electrical load and load profile requirements. Candidates would include lithium batteries. One should select and optimize the power source in light of applications.

APPENDICES

A : Bibliography

B : Diesel Engine Generator Specification

C : Static Uninterruptible Power Unit (SUPU) Specification

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APPENDIX B: DIESEL ENGINE GENERATOR SPECIFICATION

Part 1. General Requirements

1.1 Scope
1.2 Performance Requirements
Cold temperature starting, etc.
1.3 Basic Duty Requirements
Load, Voltage, Hertz, Phase, Power Factor, Elevation, Maximum Rotational Speed, Coolant, Crating, Standards, Duty Rating, Performance, Ambient Temperature, Relative Humidity, etc.
1.4 Assembly
Diesel Engine, Starting Motor, Diesel Engine Accessories, Base Plate Assembly, External Lubricating Oil Reservoir Tank, Governor, Exhaust System, Cooling System, Isolators, Engine Starting Batteries, Battery Charger, Alternator and Exciter, Voltage Regulator and Accessories, Diesel Generator Control and Transfer System, Fuel Day Tank and Fuel Transfer System, Environmental Control System, Tools and Spares, Instruction Manuals, etc.

Part 2. Description of Equipment

2.1 General Design Requirements
2.2 Capacity of Oil Reservoir Sump Tank
2.3 Diesel Engine
Duty Cycle, Rotation, Fuel, Type, etc.
2.4 Engine Cooling System
2.5 Lubricating System
2.6 Engine Fuel System
2.7 Speed Control
2.8 Starting System
2.9 Engine Control and Monitoring Equipment
2.10 Cyclic Irregularity
2.11 Exhaust System
2.12 Engine Wiring
2.13 Miscellaneous
2.14 BAttery Charger
2.15 Day Tank Fuel System
2.16 Alternator
2.17 Control and Transfer Panel
2.18 Environmental Control System

Part 3. Goods and Services

3.1 Material and Workmanship
Finishing and Painting, Spares, etc.

3.2 Instruction Manual
- -Outline drawing of unit and unit base
- -Outline drawing of panel
- -Maintenance and operation manual for engine
- -Parts catalogue for engine
- -Schematic drawing of lubricating system
- -Actual and schematic wiring diagram of engine staring and shut-down system
- -Actual and schematic wiring diagram of generator and control panel with bills of material
- -Wiring diagram of ventilating system
- -Alternator and exciter factory test data
- -Engine manufacturwe's factory test data
- -Maintenance and operation bulletins (Generator, Exciter, Voltage Regulator, Starter Motor, Batteries, Ventilating Equipment, Battery Charger, Speed Governor, Timers, Meters, Relays, etc.), etc.

3.3 Drawings

Part 4. Inspection, Test and Acceptance Procedure

4.1 Witness Acceptance Test

4.2 Examination of Product

4.3 Non-Operational Tests and Checks
- -Shaft alignment
- -Cold Resistance
- -Belt tensioning
- -Equipment Grounding
- -Electrical wiring
- -All grease lubricating points
- -Personnel safety guards
- -Air cleaner
- -Coolant
- -Lube oil type and level
- -Type of fuel
- -Isolator adjustment
- -Temperature and pressure sensors
- -Ventilating system

-Exhaust system, etc.
4.4 Operational Tests and Checks
4.5 Load Tests

Part 5. Packing

5.1 Crating, Inhibiting and Marking

Part 6. Contractor's Guarantee

6.1 Warranty

Part 7. Tender Requirements

7.1 Information to be submitted with Tender
7.2 Submission of Tenders

APPENDIX C: STATIC UNINTERRUPTIBLE POWER UNIT SPECIFICATION

Part 1. General

1.1 Specifications and References
1.2 System Objectives
1.3 Description of System
1.4 Information with Tender
1.5 Submission of Tenders
1.6 Quality Assurance
1.7 Factory Tests
Test shall be performed in supplier's factory and witnessed by design authority
1.8 Care, Operation and Start-up
1.9 Operation and Maintenance Data
1.10 Maintenance Materials
1.11 Delivery and Storage
1.12 Guarantee

Part 2. Products

2.1 Equipment
2.2 Input Power Characteristics
2.3 Output Power Requirements
2.4 Electrical Design Requirements
2.5 Mechanical Design Requirements
2.6 Instruments and Indicators

Meters:
-AC input voltage, each phase each module
-AC input current, each phase
-AC input frequency, each module
-DC voltage, each module
-DC current (battery charge/discharge), each module
-AC output voltage, each phase, each module
-AC output current, each phase, each module
-AC output frequency, each module
-Bypass line voltage, each phase
-Bypass line current each phase
-Bypass line frequency
-Load voltage, each phase, each module
-Load current, each phase, each module
-Load frequency, each module
-Output kilowatts, each module, etc.

Indicators:

-AC input breaker open, each module
-AC input output breaker closed, each module
-DC battery breaker open, each module
-DC battery breaker closed, each module
-AC output breaker open, each module
-AC output breaker closed, each module
-SUPU module OK to operate, each module
-Bypass breaker open, each module
-Bypass breaker closed, each module, etc.

2.7 Remote Status Alarm System

2.8 Batteries
Systems to include suitable high performance batteries, electrolyte, battery rack, and all accessories

Part 3. Execution

3.1 Site Inspection and Tests
Supplier to provide preventive and corrective maintenance for the system